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A Fortran Program For Calculating

The Equivalent Source Strength For The

Class I and II Flextensional Underwater

Acoustic Transducer Designs

Jack N. Boone
Department of Mechanical and Aerospace Engineering
Center For Acoustical Studies
North Carolina State University
Raleigh, North Carolina

Larry H. Royster
Department of Mechanical and Aerospace Engineering
Center For Acoustical Studies
North Carolina State University
Raleigh, North Carolina

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ABSTRACT

A Fortran program is presented which computes a normalized equivalent source strength for the Class I and approximates the Class II Flextentional Underwater Acoustic Transducer Shells. The program utilization, the input data and the output data formats are described in detail.

INTRODUCTION

This report describes a Fortran program of an equivalent source strength model for the Class I and II (Reference 1) Flextensional Underwater Acoustic Transducer Shells. Pictures of these two shell configurations are shown in Figures 1 and 2.

An approximate analytical model for the Class I type of shell design has been developed (References 2 and 3. The math model described in References 2 and 3 utilizes a numerical model in order to obtain the near- and far-field acoustic pressures for a specified displacement on the shell and associated frequency of radiation. This model is sufficient for engineering applications up through the fundamental mode of vibration provided that a so-called forbidden frequency is not encountered (Reference 4).

It is not uncommon for the effective ka of a flextensional shell to be less than one thus yielding a relatively omni-directional far-field radiation pattern. If for such design situations an equivalent source strength model was available, an approximation to the far-field pressures at a defined frequency and shell displacement would be possible. In addition, the equivalent source strength model would be more economical to utilize, computer cost, etc., and would yield important preliminary design information.

FIGURE 1

FIGURE 2
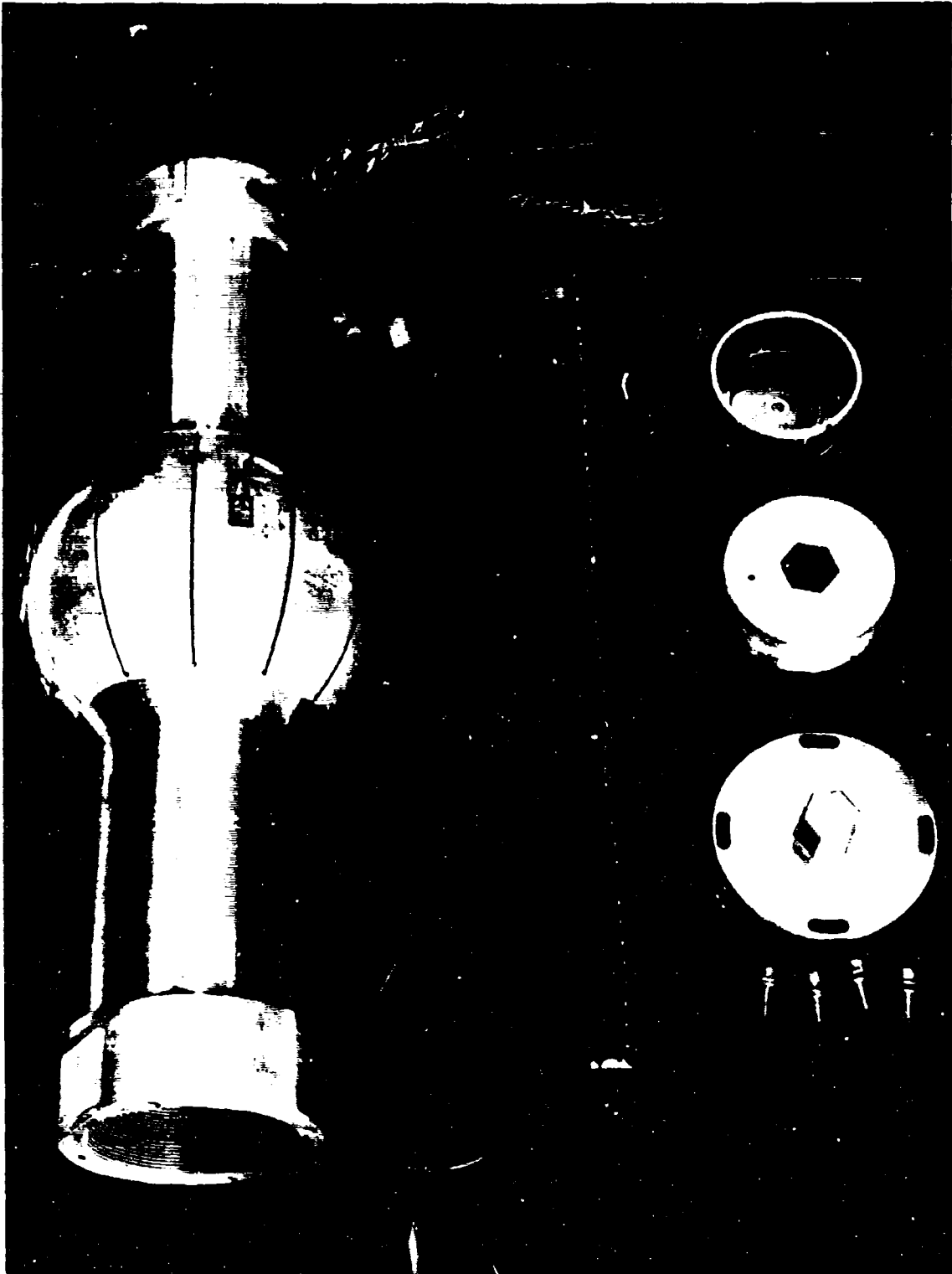
PROGRAM UTILIZATION

For a given transducer having the general configuration depicted in Figure 3, all geometric quantities pertinent to the solution of the free vibration eigenvalue problem and the computation of the source strength may be determined by specifying any one of several dimensionless parameters and the opening angle, θ_0. The parameters L/D and θ_0 are the independent variables in the accompanying FORTRAN program; L/D being selected since it is also relevant with respect to the size of the piezoelectric stack required to drive the transducer.

The solution of the approximate dynamic model involves computing the first eigenvalue and eigenvector of a 2* NP-2 square matrix, where NP is the number of control points input for generation of the discrete system equations of motion. It is suggested that, for best numerical results, NP should lie in the range $10 \leq NP \leq 15$.

The units used are immaterial since all input - output quantities are dimensionless ratios with the exception of the opening angle which is in degrees.
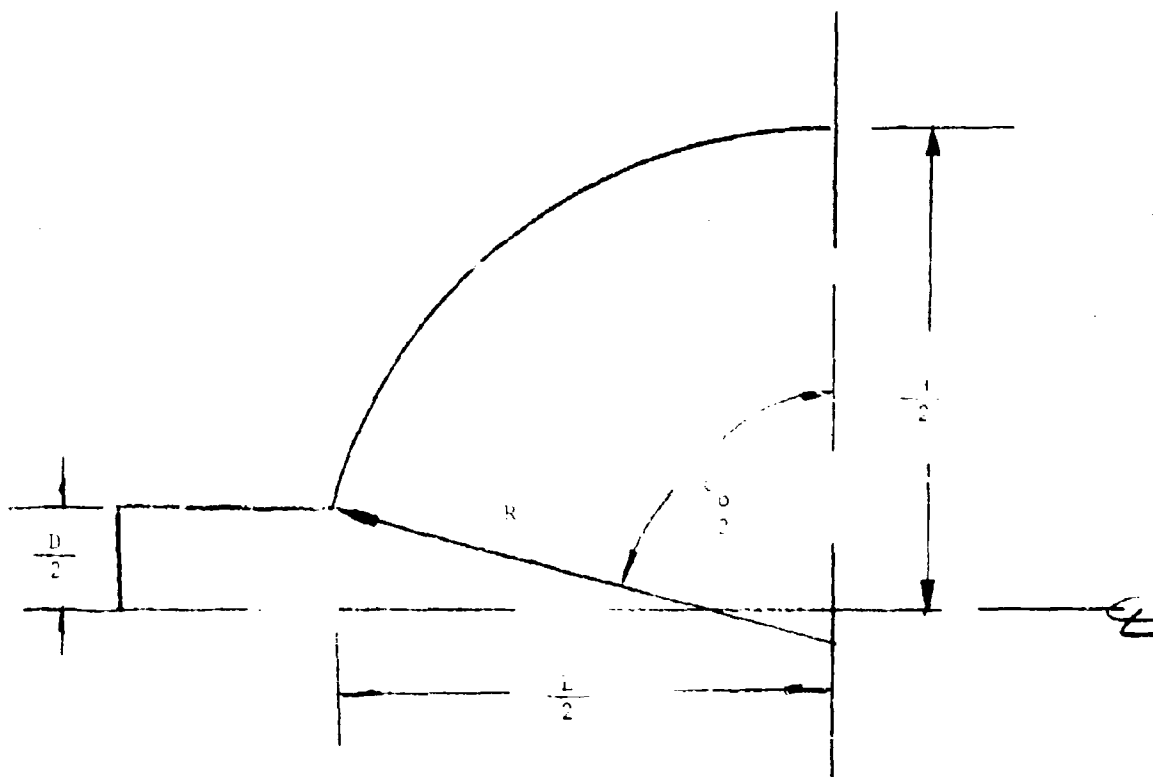
Figure 3 - Transducer Configuration

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INPUT DATA

On the first data card enter NN, the number of cases to be run consecutively. NN is input in FORMAT (I2).

On each following card enter the quantities IVC, NP, IAL, IAU, INC, RK, and RATIO in FORMAT (I1, I2, 3I3, 2F4.1).

IVC controls the printout of the components of the eigenvector normal to the surface of the transducer and the normalized radiating areas. These vectors are printed out only if IVC is entered as a non zero positive quantity.

NP is the number of control points to be defined on one half of a typical transducer element for the discrete system dynamic model.

IAL, IAU, and INC correspond to the first opening angle, the last opening angle, and the opening angle increment, respectively, desired in the output for a given RATIO. These quantities have units of degrees.

RK is the ratio of the radius of curvature of a typical transducer element to the radius of gyration of a typical element section as measured at the guided end. The dynamic model is insensitive to this parameter for RK $\geq$ 20. RK is normally input as any large positive number for thin transducer elements. RATIO = L/D.

PRINT-OUT DATA

The input quantities RATIO and NP appear as header information for each case. The output quantities THETA, RADIUS/LENGTH, HEIGHT/LENGTH, DISPL. RATIO, WIDTH RATIO, WIDTH FACTOR, COEFFICIENT AND NORM. SOURCE STR. are printed out for each opening angle where:

$$\text{THETA} = \theta_o$$

$$\text{RADIUS/LENGTH} = R/L$$

$$\text{HEIGHT/LENGTH} = H/L$$

DISPL. RATIO is the ratio of the displacement measured at the center of the circular arc formed by a typical transducer element to the corresponding horizontal displacement of the guided end.

WIDTH RATIO is the ratio of the width of a typical element as measured at the center of of circular arc to the width of the element as measured at the guided end.

WIDTH FACTOR = element width at center of arc/(1/2 arc length of element * sin (PI/N)), where N is the number of transducer elements.

COEFFICIENT is the frequency coefficient i.e. that number which, when multiplied by SQRT (E*I/m)/(L*L), yields the natural frequency in rad./sec. where E is the modulus of elasticity, I and m are the area moment of inertia and mass per unit length of a typical element as measured at the guided end, and L is as shown in Figure 3.

NORM. SOURCE STR is the source strength of the transducer normalized with respect to ((PI*D)**2)*F* DELTA where F is the frequency of excitation in cycles/sec., DELTA is the displacement amplitude of the guided end, and D is as in Figure 3. Negative values of this quantity indicate that the net volume displacement is negative when the ends of the transducer are displaced in such a manner that the transducer is elongated.

If IVC > 0, the vectors NORMAL VECTOR and NORMALIZED AREAS are also printed out. NORMAL VECTOR is the vector of eigenvector components normal to the transducer surface normalized with respect to the eigenvector component at the guided end. NORMALIZED AREAS is the vector of radiating areas associated with the discrete system control points normalized with respect to the area of the circular end section.

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FINAL REMARKS

The model presented in this report is an approximate model since several simplifying assumptions were necessary. A list of the most important assumptions made and where deemed appropriate the anticipated results of having to make such assumptions are as follows:

a) It is assumed that the external geometry of the shells can be approximated by cylindrical end sections (actual length is not considered since it is assumed that ka<1) and circular curved beams exhibiting a varying taper characteristic.

b) The cylindrical end sections do not radiate except on the ends. If the radial thickness of the cylindrical end sections is small compared to the thickness of the curved beams then most likely these end sections will contribute significantly to the overall radiation field.

c) Raidation through the slits between the curved beams is assumed to be insignificant.

d) It is assumed that the boundary condition for the curved beams is clamped-guided. Most Class I shells will approximate this boundary condition as will relatively thick Class II shell designs.

e) The present program does not allow the option of specifying the actual curved beam end mass If the end masses become large as compared to the total mass of the curved beams, as is quite possible for the Class II shell, then the eigenvector associated with the shells fundamental frequency of vibration approaches the quasi-static solution. This would result in a reduction in the predicted far-field pressures of approximately 25%.

The program described here in has been checked by comparing the predicted and measured far-field pressures for a transducer of known performance. The predicted pressures were approximately +1.5 db above the measured data. In

light of the intended use for the model described herein the above variation
is acceptable. In addition, since it is entirely possible to design a
flextensional transducer (for ka $\cdot$) with $Q_s \cdot 0$, this program should be
utilized early in the design process in order to elimate this type of
design error.

REFERENCES

1) Brigham, G. A. and L. H. Royster. Present Status in the Design of Flex-
    tensional Underwater Acoustic Transducers. Paper presented at the
    Seventy-Seventh Meeting of the Acoustical Society of America, Philadelphia,
    Pennsylvania, April, 1969.

2) Royster, L. H. The Flextentional Underwater Acoustic Transducer. J.
    Acoust. Soc. of America. 45(1): 671-682 (1969).

3) Royster, L. H. Investigation of the Design Principles of the Flextentional
    Underwater Acoustic Transducer. Contract Nonr 486(11), Part I, Final
    Report, North Carolina State University, 1967.

4) Hess, J. L. Calculation of Acoustic Fields About Arbitrary Three-Dimensional
    Bodies by a Method of Surface Source Distributions Based on Certain Wave
    Number Expansions. Report No. DAC 66901, MCDONNEL DOUGLAS, March 1968.

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C     THIS PROGRAM COMPUTES THE SOURCE STRENGTH, FREQUENCY COEFFICIENT,
C     AND A NUMBER OF GEOMETRIC PARAMETERS FOR A CLASS OF FLEXTENSIONAL
C     ACOUSTIC TRANSDUCERS COMPOSED OF AN ARRAY OF TAPERED CURVED BEAMS
C     (CIRCULAR ARCS) FORMING A SURFACE OF REVOLUTION AND EXHIBITING
C     SHORT CYLINDRICAL END SECTIONS

C     USAGE- THE FOLLOWING PARAMETERS MUST APPEAR ON THE DATA CARD
C     FOR EACH CASE- IVC, NP, IAL, IAU, INC, RK, RATIO

C     DESCRIPTION OF INPUT PARAMETERS

C     NN=NUMBERS OF DATA SETS
C     IVC=1 IF A PRINTOUT OF THE NORMALIZED AREAS AND NORMALIZED NORMAL
C     VECTORS IS DESIRED(THE TANGENTIAL COMPONENTS OF THE EIGENVECTOR ARE
C     DESTROYED IN THE NORMALIZATION), IVC=0 OTHERWISE
C     NP=THE NUMBER OF CONTROL POINTS IN HALF OF THE BEAM
C     IAL=FIRST OPENING ANGLE DESIRED IN THE OUTPUT
C     IAU=LAST OPENING ANGLE DESIRED IN THE OUTPUT
C     INC=OPENING ANGLE INCREMENT
C     RK=BEAM RADIUS/RADIUS OF GYRATION OF A TYPCIAL ELEMENT EVALUATED
C     AT THE GUIDED END
C     RATIO=CHORD SUBTENDED BY THE OPENING ANGLE/DIAMETER OF CYLINDRICAL
C     END SECTION AT THE GUIDED END

C     DESCRIPTION OF OUTPUT PARAMETERS

C     THETA=OPENING ANGLE SUBTENDED BY A TYPICAL ELEMENT OF THE ARRAY
C     RADIUS/LENGTH=BEAM RADIUS/CHORD LENGTH
C     HEIGHT/LENGTH=TRANSDUCER HEIGHT/CHORD LENGTH
C     DISPL. RATIO=RATIO OF NORMAL DISPLACEMENT AT THE BEAM CENTER TO THE
C     DISPLACEMENT OF THE GUIDED END
C     WIDTH RATIO=RATIO OF BEAM WIDTH AT THE CENTER OF THE BEAM TO THE
C     BEAM WIDTH AT THE GUIDED END
C     WIDTH FACTOR=MAXIMUM BEAM WIDTH/(ARC LENGTH OF HALF BEAM*S IN(PI/
C     1N)),N=NUMBER OF BEAMS IN THE ARRAY
C     COEFFICIENT=FREQUENCY COEFFICIENT
C     NORM. SOURCE STR.=SOURCE STRENGTH/(((PI*D)**2)*F*DEL TA), D=END
C     DIAMETER, F=FREQUENCY IN CY./SEC., DELTA=DISPLACEMENT OF GUIDED END
C     NORMAL VECTOR=NORMAL EIGENVECTOR COMPONENTS NORMALIZED ON THE
C     DISPLACEMENT OF THE GUIDED END
C     NORMALIZED AREAS=RADIATING AREAS ASSOCIATED WITH EACH DISCRETE CONTROL
C     POINT NORMALIZED WITH RESPECT TO THE AREA OF THE CYLINDRICAL END
```

```
      DIMENSION A(60,60),VU(60),RM(60),RI(30),RN(30),RS(30)
      COMMON N,M, MODE,A,VU
      PI=3.1415927
      M=1
      MODE=1
      READ(1,102)NN
102 FORMAT(I2)
      DO 1 KK=1,NN


      READ(1,103)IVC,NP,IAL,IAU,INC,RK,RATIO
103 FORMAT(I1,I2,3I3,2F4.1)
      N=2*NP-2
      WRITE(3,100)RATIO,NP
100 FORMAT('1'//////47X,'LENGTH/END DIA.-'F7.4/47X,'NO. OF CONTROL PTS
    1. IN HALF BEAM='I2////8X,'THETA',3X,'RADIUS/LENGTH',3X,'HEIGHT/LEN
    2GTH',3X,'DISPL. RATIO',3X,'WIDTH RATIO',3X,'WIDTH FACTOR',3X,'COEF
    3FICIENT',3X,'NORM. SOURCE STR.')
      DO 1 LA=IAL,IAU,INC
      OA=LA*PI/180.
      RR=SIN(OA/2.)/RATIO
      CALL COEFF(N,NP,OA,RR,SI,PHI,RM,RI,RN,RS)
      CALL STIFF(N,NP,RK,SI,PHI,A,RM,RI,RN)
      CALL GIVENS
      VU(1)=SQRT(VU(1))*COS(PHI/2.)*(S IN(OA/2.)**2)/(SIN(PHI/2.)**2)
      DO 2 I=1,N
      A(I,1)=A(I,1)/SQRT(RM(I))
2 CONTINUE
      QSN=A(1,1)/ABS(A(1,1))
      DO 3 I=2,N,2
      K=I/2+1
      QSN=QSN+A(I,1)*RS(K)/ABS(A(1,1))
3 CONTINUE
      IF(A(1,1))4,4,5
4 QSN=-QSN
5 RL=1./(2.*SIN(OA/2.))
      THL=(RR+1.-COS(OA/2.))/SIN(OA/2.)
      DR=A(N,1)/A(1,1)
      WR=RI(NP)
      WF=4.*(1.-COS(OA/2.)+SIN(OA/2.)/RATIO)/OA
      OA=OA*180./PI
      WRITE(3,101)OA,RL,THL,DR,WR,WF,VU(1),QSN
101 FORMAT(//F13.1,2E16.6,E15.5,E14.5,E15.5,E14.5,E18.6)
      IF(IVC)1,1,6
6 IF(A(1,1))7,7,8
7 A(1,1)=-A(1,1)
      DO 9 I=2,N,2
      A(I,1)=-A(I,1)
```

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```
    9 CONTINUE
    8 DO 10 I=2,N,2
      K=I/2+1
      A(K,1)=A(I,1)/A(1,1)
   10 CONTINUE
      A(1,1)=1.
      WRITE(3,104)
  104 FORMAT(//34X,'NORMAL VECTOR',34X,'NORMALIZED AREAS'//)
      WRITE(3,105)(A(I,1),RS(I),I=1,NP)
  105 FORMAT(35X,E12.5,36X,E12.5)
    1 CONTINUE
      END
```

```
      SUBROUTINE COEFF(N,NP,OA,RR,SI,PHI,RM,RI,RN,RS)
      DIMENSION RM(60),RI(30),RN(30),RS(30)
      PI=3.1415927
      S1=(PI-OA)/2.
      PHI=OA/(2.*(NP-1.))
      OA2=OA/2.
      PHI2=PHI/2.
      D=COS(OA/2.)-RR
      RI(1)=1.
      RN(1)=1.        RS(1)=1
      DO 1 J=2,NP
      RI(J)=(COS(OA2-(J-1.)*PHI)-D)/RR
      RN(J)=2.*RI(J)*RI(J-1)/(RI(J)+RI(J-1))
      RS(J)=2.*(2.*SIN(PHI2)*COS(OA2-(J-1.)*PHI)-D*PHI)/(RR*RR)
    1 CONTINUE
      RS(2)=2.*(2.*SIN(3.*PHI/4.)*COS(OA/2.-3.*PHI/4.)-D*3.*PHI/2.)/(RR*
     1RR)
      RS(NP)=2.*(SIN(PHI2)-D*PHI2)/(RR*RR)
      RM(1)=1.
      RM(N)=RI(NP)/2.
      M=N-2
      DO 2 J=2,M,2
      RM(J)=RI(J/2+1)
      RM(J+1)=RM(J)
    2 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE STIFF(N,NP,RK,SI,PHI,A,RM,RI,RN)
      DIMENSION A(60,60),RM(60),RN(30),RI(30)
      C=SIN(PHI/2.)/COS(PHI/2.)
      C2=SIN(SI)/COS(SI)
      P=(2.*RK*SIN(PHI/2.))**2
      DO  1 I=1,N
      DO  1 J=1,N
      A(1,J)=0.0
    1 CONTINUE
      A(1,1)=((C*(C+C2)*RN(2)*P-(2.+RI(2))*(C*C2-1.))*COS(SI)+((C+C2*RN
     1(2)*P+(2.+RI(2))*C*(C*C2-1.))*SIN(SI))*COS(SI)
      A(1,2)=(C*(C+C2)*RN(2)*P+2.*(1.+RI(2))*(C*C2-1.))*COS(SI)
      A(1,3)=((C+C2)*RN(2)*P-2.*C*(C*C2-1.))*COS(SI)
      A(1,4)=-RI(2)*(C*C2-1.)*COS(SI)
      A(1,5)=RI(2)*C*(C*C2-1.)*COS(SI)
      A(2,2)=(RN(2)+RN(3))*P*C*C+2.+4.*RI(2)+RI(3)
      A(2,3)=C*((RN(2)-RN(3))*P-2.+RI(3))
      A(2,4)=RN(3)*P*C*C-2.*(RI(2)+RI(3))
      A(2,5)=C*(RN(3)*P+2.*RI(2))
      A(2,6)=RI(3)
      A(2,7)=-RI(3)*C
      A(3,3)=(RN(2)+RN(3))*P+(2.+RI(3))*C*C
      A(3,4)=-C*(RN(3)*P+2.*RI(3))
      A(3,5)=-RN(3)*P
      A(3,6)=RI(3)*C
      A(3,7)=-RI(3)*C*C
      K1=N-4
      K2=N-3
      K3=N-2
      K4=N-1
      J1=NP-3
      J2=NP-2
      J3=NP-1
      A(K1,K1)=(RN(J2)+RN(J3))*P*C*C+RI(J1)+4.*RI (J2)+RI(J3)
      A(K1,K2)=C*((RN(J2)-RN(J3))*P-RI(J1)+RI(J3))
      A(K1,K3)=RN(J3)*P*C*C-2.*(RI(J2)+RI(J3))
      A(K1,K4)=C*(RN(J3)*P+2.*RI(J2))
      A(K1,N)=RI(J3)
      A(K2,K2)=(RN(J2)+RN(J3))*P+(RI(J1)+RI(J3))*C*C
      A(K2,K3)=-C*(RN(J3)*P+2.*RI(J3))
      A(K2,K4)=-RN(J3)*P
      A(K2,N)=RI(J3)*C
      A(K3,K3)=(RN(J3)+RN(NP))*P*C*C+RI(J2)+4.*RI(J3)+2.*RI(NP)
      A(K3,K4)=C*((RN(J3)-RN(NP))*P-RI(J2)+2.*RI(NP))
      A(K3,N)=RN(NP)*P*C*C-2.*RI(J3)+RI(NP))
      A(K4,K4)=(RN(J3)+RN(NP))*P+(RI(J2)+2.*RI(NP))*C*C
      A(N,N)=RN(NP)*P*C*C+RI(J3)+2.*RI(NP)    A(K4,N)=-C*(RN(NP)*P+2.*RI(NP))
      JM=N-6
      DO 2 I=4,JM,2
      DO 2 J=4,JM,2
      IF(I-J)2,3,2
```

```
3 K=I/2+1
  A(I,J)=(RN(K)+RN(K+1))*P*C*C+RI(K-1)+4.*RI(K)+RI(K+1)
  A(I,J+1)=C*((RN(K)-RN(K+1))*P-RI(K-1)+RI(K+1))
  A(I,J+2)=RN(K+1)*P*C*C-2.*(RI(K)+RI(K+1))
  A(I,J+3)=C*(RN(K+1)*P+2.*RI(K))
  A(I,J+4)=RI(K+1)
  A(I,J+5)=-RI(K+1)*C
  M=I+1
  L=J+1
  A(M,L)=(RN(K)+RN(K+1))*P+(RI(K-1)+RI(K+1))*C*C
  A(M,L+1)=-C*(RN(K+1)*P+2.*RI(K+1))
  A(M,L+2)=-RN(K+1)*P
  A(M,L+3)=RI(K+1)*C
  A(M,L+4)=-RI(K+1)*C*C
2 CONTINUE
  DO 4 I=1,N
  DO 4 J=1,N
  A(J,1)=A(I,J)
4 CONTINUE
  DO 5 I=1,N
  DO 5 J=1,N
  A(I,J)=A(I,J)/SQRT(RM(I)*RM(J))
5 CONTINUE
  RETURN
  END
```

```
      SUBROUTINE GIVENS
      DIMENSION A(60,60),B(60,60),DIAG(60),VU(60),VL(60),SD(60),
     1Q(60),S(60),C(60),D(60),IND(60),U(60)
      COMMON N,M,MODE,A,VU
      EQUIVALENCE (P,PRODS),(TAU,BETA),(T,SMALLD),(II,MATCH),(VL(1),D(1)
     1),(Q(1),S(1))

C     CALCULATE NORM OF MATRIX

      ANORM=0.
      DO 1 I=1,N
      SD(I)=0.
      DO 1 J=1,N
    1 ANORM=ANORM+A(I,J)*A(I,J)
      ANORM=SQRT(ANORM)

C     GENERATE IDENTITY MATRIX

      IF(M)1000,11,1000
 1000 DO 7 I=1,N
      DO 7 J=1,N
      IF(I-J)6,1001,6
 1001 B(I,J)=1.
      GO TO 7
    6 B(I,J)=0.
    7 CONTINUE

C     PERFORM ROTATIONS TO REDUCE MATRIX TO JACOBI FORM

   11 NN=N-2
      IF(NN)100,21,1003
 1003 DO 15 I=1,NN
      II=I+2
      DO 15 J=II,N
      T1=A(I,I+1)
      T2=A(I,J)
      IF(T2)1004,15,1004
 1004 CALL ROTATE(T1,T2,SN,CSN)
      DO 12 K=1,N
      T2=CSN*A(K,I+1)+SN*A(K,J)
      A(K,J)=CSN*A(K,J)-SN*A(K,I+1)
   12 A(K,I+1)=T2
      DO 13 K=1,N
      T2=CSN*A(I+1,K)+SN*A(J,K)
      A(J,K)=CSN*A(J,K)-SN*A(I+1,K)
   13 A(I+1,K)=T2
      IF(M)1005,15,1005
 1005 DO 14 K=1,N
      T2=CSN*B(K,I+1)+SN*B(K,J)
```

```
      B(K,J)=CSN*B(K,J)-SN*B(K,I+1)
   14 B(K,I+1)=T2
   15 CONTINUE

C     MOVE JACOBI ELEMENTS AND INITIALIZE EIGENVALUE BOUNDS

   21 DO 22 I=1,N
      DIAG(I)=A(I,I)
      VU(I)=ANORM
   22 VL(I)=-ANORM
      DO 23 I=2,N
      SD(I-1)=A(I-1,I)
   23 Q(I-1)=SD(I-1)*SD(I-1)

C     DETERMINE SIGNS OF PRINCIPAL MINORS

      TAU=0.
      I=1
   35 MATCH=0
      T2=0.
      T1=1.
      DO 26 J=1,N
      P=DIAG(J)-TAU
      IF(T2)1007,27,1007
 1007 IF(T1)1008,28,1008
 1008 T=P*T1-Q(J-1)*T2
      GO TO 29
   27 IF(T1)1009,30,30
 1009 T1=-1.
      T=-P
      GO TO 29
   30 T1=1.
      T=P
      GO TO 29
   28 IF(Q(J-1))1010,30,1010
 1010 IF(T2)31,1011,1011
 1011 T=-1.
      GO TO 29
   31 T=1.

C     COUNT AGREEMENTS IN SIGN

   29 IF(T1)32,1012,1012
 1012 IF(T)34,33,33
   32 IF(T)33,34,34
   33 MATCH=MATCH+1
   34 T2=T1/ABS(T1)
   26 T1=T/ABS(T1)
```

GIVENS (continued)

```
C     ESTABLISH TIGHTER BOUNDS ON EIGENVALUES

      DO 41 K=1,MODE
      IF(K-N+MATCH)1014,1014,42
1014  IF(VU(K)-TAU)41,41,1015
1015  VU(K)=TAU
      GO TO 41
42    IF(VL(K)-TAU)1018,41,41
1018  VL(K)=TAU
41    CONTINUE
45    IF(VU(I)-VL(I)-5.E-6)43,43,1016
1016  IF(VU(I))1017,44,1017
1017  IF(ABS(VL(I)/VU(I)-1.)-5.E-6)43,43,44
43    I=I+1
      IF(I-MODE)1019,1019,51
1019  GO TO 45
44    TAU=(VL(I)+VU(I))/2.
      GO TO 35
51    IF(M)100,100,1020
1020  IF(N-MODE)1021,1021,1022
1022  M=MODE
1021  DO 52 I=1,N
      DO 52 J=1,N
52    A(I,J)=0.
      DO 53 I=1,M
      IF(I-1)1029,54,1029
1029  IF(VU(I)-VU(I-1)-5.E-6)55,55,1023
1023  IF(VU(I))1024,54,1024
1024  IF(ABS(VU(I-1)/VU(I)-1.)-5.E-6)55,55,54
54    CSN=1.
      SN=0.
      DO 56 J=1,N
      IF(J-1)1025,57,1025
1025  CALL ROTATE(T1,T2,SN,CSN)
      S(J-1)=SN
      C(J-1)=CSN
      D(J-1)=T1*CSN+T2*SN
57    T1=(DIAG(J)-VU(I))*CSN-BETA*SN
      T2=SD(J)
56    BETA=SD(J)*CSN
      D(N)=T1
      DO 58 J=1,N
58    IND(J)=0
55    SMALLD=ANORM
      DO 60 J=1,N
      IF(IND(J)-1)1026,60,60
1026  IF(ABS(SMALLD)-ABS(D(J)))60,60,1027
1027  SMALLD=D(J)
```

```
      NN=J
  60  CONTINUE
      IND(NN)=1
      ........ ..
      IF(NN-1)1028,53,1028
1028  DO 61 K=2,NN
      II=NN+1-K
      A(II+1,1)=C(II)*PRODS
  61  PRODS=-PRODS*S(II)
  53  A(1,1)=PRODS

C     FORM MATRIX PRODUCT OF ROTATION MATRIX WITH JACOBI VECTOR MATRIX

      DO 66 J=1,M
      DO 67 K=1,N
  67  U(K)=A(K,J)
      DO 66 I=1,N
      A(I,J)=0.
      DO 66 K=1,N
  66  A(I,J)=B(I,K)*U(K)+A(I,J)
 100  RETURN
      END


      SUBROUTINE ROTATE(A,B,C,D)
      E=SQRT(A*A+B*B)
      D=A/E
      C=B/E
      RETURN
      END
```

APPENDIX B

Listing of a Typical Output Data Set

TYPICAL OUTPUT

LENGTH/END DIA.= 1.2600

NO. OF CONTROL PTS. IN HALF BEAM=15

THETA	RADIUS/LENGTH	HEIGHT/LENGTH	DISPL. RATIO	WIDTH RATIO	WIDTH FACTOR	COEFFICIENT	NORM. SOURCE STR.
102.0	0.643380E 00	0.127063E 01	-0.19610E 01	0.16010E 01	0.22187E 01	0.16698E 02	-0.234460E 01

NORMAL VECTOR	NORMALIZED AREAS
0.10000E 01	0.10000E 01
0.69187E 00	0.32734E 00
0.53385E 00	0.23737E 00
0.31990E 00	0.25156E 00
0.65892E-01	0.26471E 00
-0.21328E 00	0.27677E 00
-0.50371E 00	0.28771E 00
-0.79261E 00	0.29746E 00
-0.10684E 01	0.30599E 00
-0.13207E 01	0.31327E 00
-0.15403E 01	0.31926E 00
-0.17195E 01	0.32395E 00
-0.18521E 01	0.32731E 00
-0.19335E 01	0.32934E 00
-0.19610E 01	0.16501E 00

TYPICAL OUTPUT (continued)

108.0   0.618035E 00   0.130317E 01   -0.18372E 01   0.16420E 01   0.22373E 01   0.16727E 02   -0.212407E 01

NORMAL VECTOR

0.10000E 01
0.72579E 00
0.57543E 00
0.37029E 00
0.12604E 00
-0.14329E 00
-0.42432E 00
-0.70451E 00
-0.97226E 00
-0.12172E 01
-0.14302E 01
-0.16038E 01
-0.17320E 01
-0.18107E 01
-0.18372E 01

NORMALIZED AREAS

0.10000E 01
0.33404E 00
0.24338E 00
0.25874E 00
0.27302E 00
0.28613E 00
0.29804E 00
0.30867E 00
0.31798E 00
0.32593E 00
0.33249E 00
0.33762E 00
0.34130E 00
0.34352E 00
0.17213E 00

(25)

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	2b. GROUP

3. REPORT TITLE

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13. ABSTRACT

A Fortran program is presented which computes a normalized equivalent source strength for the Class I and approximates the Class II Flextensional Underwater Acoustic Transducer Shells. The program utilization, the input data and the output data formats are described in detail.

DD FORM 1473 1 JAN 64

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Flextensional						
Underwater						
Acoustic						
Transducer						
Source Strength						
Curved Beams						
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